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辽宁西部早白垩世义县组一新的手盗龙类[1)]

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摘要 我国辽西早白垩世热河群义县组和九佛堂组近年来产出大量恐龙化石,已知兽脚类恐龙包括8属10种,其中6属8种保存有原始羽毛或者羽毛结构。已经报道的属种均产自朝阳地区。2001年,中国科学院古脊椎动物与古人类研究所辽西野外考察队在邻近朝阳的锦州地区义县头台乡王家沟义县组下部采集到一件恐龙标本。这一标本保存了较为完整的肩带和前肢,在骨骼化石附近还保存了皮肤结构。通过研究对比,我们建立了手盗龙类的一个新属种:长掌义县龙(*Yixianosaurus longimanus* gen. et sp. nov.)。

依据以下特征将长掌义县龙归入手盗龙类:肩胛骨明显短于肱骨、肩臼窝的乌喙骨部分小、乌喙骨近四方形、尺骨向后弯曲以及桡骨细。

长掌义县龙手部的相对长度以及手指各指节的相对比例不同于已知手盗龙类。原始兽脚类恐龙的手部一般短于肱骨;手盗龙手部加长,长于肱骨;原始鸟类的手部相对更长,但进步鸟类出现反转,手部次生变短。长掌义县龙手部的相对长度在非鸟兽脚类恐龙当中仅比原始祖鸟(*Protarchaeopteryx*)(Ji et al., 1998)和树息龙(*Epidendrosaurus*)(Zhang et al., 2002)短。次末端指节加长是兽脚类恐龙的一个进步特征,长掌义县龙具有这一特征。比如,长掌义县龙的手指指节 II-2 长于掌骨 II,在已知兽脚类恐龙当中,只有树息龙的手指指节 II-2 长于掌骨 II。长掌义县龙手指指节 II-2/ II-1 的比率为1.44,是兽脚类恐龙当中最高的之一。长掌义县龙的手指指节 III-3 也明显加长,其 III-3/ III-1 比率为2.44,大于其他所有恐龙。长掌义县龙手部的相对长度以及手指各指节的相对比例与树息龙最为接近,但后者的 III-3 相对很短,只有 III-1 的86 %。从总体上看,长掌义县龙的手部形态和较为进步的手盗龙类更为相似,因此有可能代表这一类群中较为进步的成员。

长掌义县龙次末端指节的明显加长指示这种恐龙手的抓握能力很强,这可能是对树栖习性的一种适应。长掌义县龙代表报道于辽西地区早白垩世的第11种兽脚类恐龙,也是已知的第9种保存羽毛结构的恐龙,这一发现增加了热河群兽脚类恐龙的分异度。

关键词 辽宁义县,早白垩世,义县组,手盗龙类

中图法分类号 Q915.864

A NEW MANIRAPTORAN DINOSAUR FROM THE EARLY CRETACEOUS YIXIAN FORMATION OF WESTERN LIAONING

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Abstract A specimen collected from the Early Cretaceous Yixian Formation, Jehol Group of Liaoning,

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China, represents a new genus and species of maniraptoran theropod. It comprises almost complete articulated pectoral girdles, forelimbs and some ribs and is here named *Yixianosaurus longimanus* gen. et sp. nov. Diagnostic features of the new species include manus 140 % as long as humerus, manual phalanx II-2 longer than metacarpal II, manual phalanx III-3 244 % as long as phalanx III-1, and manual phalanx III-2 bearing a proximoventral heel. With the integuments preserved on the holotype specimen, *Y. longimanus* represents the ninth feathered dinosaur species reported from western Liaoning. The elongated penultimate phalanges of *Y. longimanus* indicate an improved grasping capability and might represent an adaptation to the arboreal habit. The discovery of *Y. longimanus* increases the diversity of theropod dinosaurs in the Jehol Fauna.

Key words Yixian, Liaoning, Early Cretaceous, Yixian Formation, Maniraptora

1 Introduction

For the last few years, the Jehol Group of western Liaoning, China, has produced spectacular fossil remains, including the feathered dinosaurs. To date there are eight species of feathered dinosaurs reported from the area (Chen et al., 1998; Ji et al., 1998; Xu et al., 1999a, b, 2000, 2003; Zhou and Wang, 2000). These discoveries have significantly advanced our understanding of the origin of birds and their flight, and the origin and early evolution of feathers. In 2001, an incomplete maniraptoran skeleton was collected from the lower part of the Yixian Formation at Wangjiagou, Yixian, western Liaoning, a locality that is geographically close to the famous feathered dinosaur site of Sihetun in Beipiao, western Liaoning. Here we describe this specimen and erect a new genus and species.

2 Systematic paleontology

Theropoda Marsh, 1881

Maniraptora Gauthier, 1986

Yixianosaurus longimanus **gen. et sp. nov.**

(Figs. 1～2)

Holotype IVPP V 12638 (Institute of Vertebrate Paleontology and Paleoanthropology, Beijing), articulated remains of almost complete shoulder girdles and forelimbs, and some ribs (Figs. 1～2).

Horizon and locality Lower part of Yixian Formation, Wangjiagou, Yixian County, western Liaoning, China; Early Cretaceous (Swisher et al., 1999).

Etymology Yixian for Yixian County that includes the type locality, sauros, meaning reptile (Greek); longimanus (long, long, Latin; manus, hand, Latin) for the significantly elongated manus.

Diagnosis A small-sized maniraptoran distinguishable from all other known maniraptoran species but *Epidendrosaurus* in having an unusually long manual phalanx II-2 (longer than metacarpal II); it differs from *Epidendrosaurus* as well as other maniraptorans in having a proportionately much longer manual phalanx III-3 (244 % as long as manual phalanx III-1 in *Yixianosaurus* compared to 86 % in *Epidendrosaurus*); *Yixianosaurus* also differs in having a longer manus (manus/humerus length ratio = 1.4) than other maniraptorans but *Confuciusornis*, *Protarchaeopterys*, *Epidendrosaurus* and having a proximoventral heel on manual phalanx III-2 (a feature shared with basal dromaeosaurs).

3 Description

The ontogenetic stage of the holotype, the only specimen, is difficult to determine because the preserved elements provide little ontogenetic information. Some weak evidence can be obtained,



图 1　长掌义县龙(新属新种)正型标本(IVPP V 12638) ,**比例尺** = 5cm

Fig. 1　Photograph of the holotype of *Yianxianosaurus longimanus* gen. et sp. nov. (IVPP V 12638) , Scale bar = 5 cm

however , to infer the ontogenetic status of the specimen. The carpals are well ossified and all bones lack the fine striations usually seen in juvenile specimens. This evidence suggests the holotype is not a juvenile , and lack of fusion between the scapula and coracoid may suggest a sub-adult. Nevertheless , with an 89-mm-long humerus , the holotype represents one of the smallest non-avian theropods reported to date (Table 1) .

The pectoral girdle is represented by complete right and incomplete left scapulae and coracoids. The scapula is significantly shorter than the humerus , as in some derived maniraptorans (Xu et al. , 1999b) . The scapular blade is strap-shaped , with nearly parallel dorsal and ventral margins. Proximally , the acromial process extends anteriorly well beyond the glenoid fossa as in

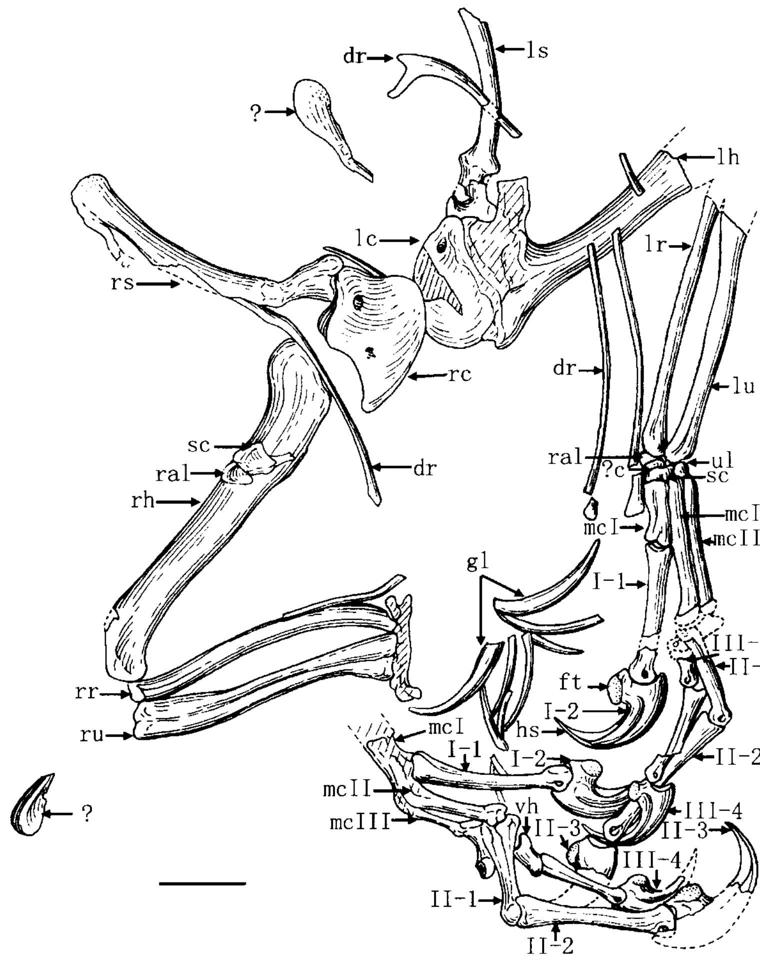


图 2 长掌义县龙(新属新种)正型标本素描(IVPP V 12638) ,**比例尺** = 2cm

Fig. 2 Line-drawing of the holotype of *Yianxianosaurus longimanus* gen. et sp. nov. (IVPP V 12638) , scale bar = 2 cm

Abbreviations **简字说明**: ?c , ?centrale **中央骨**; dr , dorsal rib **背肋**; ft , flexor tubercle **屈肌结节**;gl , gastrolia **腹膜肋**; hs , horny sheath **角质鞘**; I-1 to IV-4 , manual phalanx I-1 to IV-4 **指节** I-1 **到** IV-4 ; lc , left coracoid **左乌喙骨**; 1h , left humerus **左肱骨**;lr , left radius **左桡骨**;ls , left scapula **左肩胛骨**;lu , left ulna **左尺骨**; mcI-III, metacarpal I-III **掌骨** I-III; ral , radiale **桡侧腕骨**; rc , right coracoid **右乌喙骨**; rh , right humerus **右肱骨**; rr , right radius **右桡骨**; rs , right scapula **右肩胛骨**; ru , right ulna **右尺骨**; sc , seminulate carpal **半月形腕骨**; ul , ulnare **尺侧腕骨**; vh , ventral heel **腹跟突**

some derived maniraptorans (Xu , 2002) . The ventral margin curves sharply toward the posterior rim of the glenoid fossa , a feature seen in primitive theropods , but this is likely to be a preservational artifact. The large plate-shaped coracoid is sub-quadralic in outline as in most coelurosaurians (Gauthier , 1986) . It is proportionally large , with an anteroposterior length of 24 mm , about 38 % the scapular length. The coracoidal portion of the glenoid fossa appears to be proportionally small as in derived maniraptorans , a feature often associated with the laterally faced glenoid fossa (Xu , 2002) .

表 1 长掌义县龙(新属新种) 正型标本(IVPP V 12638) 保存骨骼的测量长度

Table 1 Lengths of preserved elements in the holotype of Yixianosaurus longimanus **gen. et sp. nov. (IVPP V 12638)** (mm)

	right	left		right	left
Scapula	65	45 #	Ⅰ-2	25	26
Humerus	89	61 #	Ⅱ-1	25	26
Ulna	64	62	Ⅱ-2	36	38
Radius	63	63	Ⅱ-3	28	
Metacarpal Ⅰ	13 *	14.5	Ⅲ-1	9 *	
Metacarpal Ⅱ	35	36	Ⅲ-2	8	
Metacarpal Ⅲ	31 #	34	Ⅲ-3	22	
Manual digit Ⅰ-1	34	33	Ⅲ-4	23	22.5

* indicates estimated or approximate value ; # indicates preserved length.

As in the Dromaeosauridae (Xu , 2002) , the humerus has a relatively short deltopectoral crest (about 30 % the humerus length) . The ulna is bowed posteriorly , with a weak olecranon process , as in advanced coelurosaurians (Gauthier , 1986) . The radius is approximately 71 % the length of the humerus , and much thinner than the ulna. For comparison , some basal dromaeosaurs and many birds have proportionately thinner radii (Xu , 2002) . The radius appears to be curved , unusual among coelurosaurians. This may be a preservation artifact , however. The distal end is semi-lunate , a derived feature seen only in birds among theropods.

The carpus is comprised of four carpals. The largest of the four is the semilunate carpal which covers the proximal end of metacarpal I and touches the medial side of the proximal end of metacarpal Ⅱ. This is different from the condition seen in most other maniraptorans from Liaoning where the semilunate covers mainly the proximal end of metacarpal Ⅱ. The radiale is the second largest carpal preserved. It has a well developed concave proximal articular surface , matching perfectly with the distal end of the radius. Two other carpals are present and may be the centrale and ulnare. The latter is preserved close to the proximal end of metacarpal Ⅲ and is therefore also likely to be a distal carpal , which is reported to be present in *Archaeopterys* (Feduccia , 1999) .

Metacarpal I is about 39 % the length of metacarpal Ⅱ. Metacarpal Ⅲ is slightly shorter than metacarpal Ⅱ and is much more slender than the other metacarpals. It is not distinctively bowed laterally as in some other maniraptorans (Xu , 2002) . Manual phalanx Ⅰ-1 is long and the combined lengths of phalanx Ⅰ-1 and metacarpal I are about 133 % metacarpal Ⅱ length. The manual phalanx Ⅱ-2 is significantly elongated , even longer than metacarpal Ⅱ. This feature has not been reported in other maniraptorans with the exception of a recently reported bizarre maniraptoran *Epidendrosaurus* (Zhang et al. , 2002) . The penultimate phalanx of the third digit is also significantly elongated. It is about 129 % the combined lengths of phalanx Ⅲ-1 and Ⅲ-2. As in basal dromaeosaurs (Xu , 2002) , phalanx Ⅲ-2 bears a prominent proximoventral heel , suggesting a rigid articulation. A noteworthy feature is the dorsally positioned collateral ligament pits on all manual phalanges , which suggest a strong extension capability. The manual unguals are strongly curved, with massive flexor tubercles located near the proximal articular surfaces. The flexor tubercles are transversely expanded distally , with rough surfaces. The horny sheath is well preserved and the tip is pointed. Among the three unguals , the middle one is the largest and the third one the smallest , but the size difference is minor.

The carbonized integument is preserved adjacent to the preserved bone. They are similar in preservation to the contour feathers in some birds from the Yixian Formation of western Liaoning and show no detailed structure.

4 Discussion

Y. longimanus represents the ninth feathered non-avian theropod reported from western Liaoning to date. Although the preserved material is limited, it provides many phylogenetic characters for comparison.

The maniraptoran status of *Y. longimanus* is indicated by the following features: short scapula, relatively small coracoidal portion of the glenoid fossa, large sub-quadratic coracoid, bowed ulna, and thin radius (Gauthier, 1986; Makovicky and Sues, 1998; Sereno, 1999; Norell et al., 2001; Xu et al., 2002; Xu, 2002). The scapula of *Y. longimanus* is significantly shorter than the humerus, a derived feature seen in Maniraptora (Xu et al., 1999b, 2002). In primitive theropods, the scapula is either longer or sub-equal in length to the humerus and this primitive condition is seen in *Caudipteryx* (Zhou et al., 2000) and some derived dromaeosaurs. As in the Paraves, the coracoidal portion of the glenoid fossa is small in *Y. longimanus*, a feature often associated with the laterally faced glenoid fossa (Xu, 2002). The posteriorly bowed ulna and relatively thin radius seen in *Y. longimanus* also characterize maniraptoran dinosaurs (Xu, 2002).

表2 一些兽脚类恐龙肩带和前肢骨骼的相对长度

Table 2 Relative proportions of shoulder and forelimb elements in some theropods

	manus/humerus	scapula/humerus	II-2/mc II	II-2/II-1	III-3/III-1
Coelophysis	0.79	0.95	0.54	1.13	1.39
Compsognathus	0.85	0.97	0.74	0.74	?
Gallimimus	0.69	0.85	0.87	1.87	2.06
Oviraptor	1.22	0.56	0.57	0.88	1.24
Caudipteryx	1.24	1.11	0.86	1.35	—
Velociraptor	?	?	0.90	1.46	1.83
Sinornithosaurus	1.13	0.63	0.56	1.10	1.28
Protarchaeopteryx	1.60	?	0.88	1.26	2.01
Epidendrosaurus	1.70	0.66	1.03	1.69	0.86
Archaeopteryx	1.25	0.63	0.74	1.37	2.23
Confuciusornis	1.45	0.78	0.80	1.14	1.24
Yixianosaurus	1.40	0.71	1.04	1.44	2.44

? indicates unknown; —indicates inapplicable; Data for other theropods are from Chiappe et al., 1999; Colbert, 1989; Ji et al., 1998; Norell and Makovicky, 1997, 1999; Ostrom, 1978; Wellnhofer, 1974, 1992, 1993; Xu, 2002; Zhang et al., 2002; Zhou et al., 2000.

Relative manual length and manual phalangeal proportions can indisputably distinguish *Y. longimanus* from other known maniraptorans and also provide information for a more specific phylogenetic position of *Y. longimanus* (Table 2). An evolutionary trend toward birds is the elongation of the manus. Primitively in theropods the manus is shorter than the humerus; maniraptorans have proportionately much longer manus that are longer than the humerus (Table 2). In basal birds the manus is proportionately even longer, though more derived birds display a reversed condition. The manus of *Y. longimanus* is proportionately longer than all other known non-avian maniraptorans except *Protarchaeopteryx* (Ji et al., 1998) and *Epidendrosaurus* (Zhang et al., 2002). The phalangeal proportions have complicated changes among maniraptoran dinosaurs. Although in general the primitive theropods have relatively shorter penultimate phalanges, many advanced theropods also display the same condition. Nevertheless the elongated penultimate phalanges seem to represent a derived condition among theropod dinosaurs and *Y. longimanus* share this feature. For example, *Y. longimanus* has an unusually long manual phalanx II-2 that is even

longer than metacarpal Ⅱ. Although some theropods have relatively long phalanx Ⅱ-2, none but *Epidendrosaurus has phalanx* Ⅱ-*2 longer than metacarpal* Ⅱ *(Table 2). The manual phalanx* Ⅱ-*2/* Ⅱ-1 length ratio is 1.44 in *Y. longimanus*, which is among the largest in the Theropoda. Manual phalanx Ⅲ-3 is also significantly elongated in *Y. longimanus*, with a ratio of Ⅲ-3/Ⅲ-1 being 2.44. This ratio is larger than that of other known maniraptorans. The relative manual length and manual phalangeal proportions in *Y. longimanus* are more similar to those in *Epidendrosaurus* than in other maniraptorans. However, *Epidendrosaurus* differs in having a fairly short manual phalanx Ⅲ-3 relative to Ⅲ-1, with the former about 86 % as long as the latter, which is unusual among maniraptorans. In general the manual morphology of *Y. longimanus* is similar to that of advanced maniraptorans, suggesting that *Y. longimanus* might represent a derived member of the group.

Recent coelurosaurian discoveries from western Liaoning and Nei Mongol support the hypothesis that the forelimb might be used to climb trees toward the transition to birds (Chatterjee, 1997; Zhang et al., 2002). The discovery of *Y. longimanus* provides further evidence for this hypothesis. The elongation of distal phalanges and the strongly curved manual unguals in *Y. longimauns* suggest a strong grasping capability and might represent an adaptation to the arboreal habit, as suggested for some other maniraptorans (Table 2; Xu, 2002; Zhou and Farlow, 2001).

So far ten theropod species have been reported from the Early Cretaceous Jehol Group of western Liaoning, China. They are the compsognathid *Sinosauropteryx prima*, the therizinosauroid *Beipiaosaurus inexpectus*, the oviraptorosaurians *Caudipteryx zoui*, *C. dongi*, and *Incisivosaurus gauthieri*, the troodontid *Sinovenator changii*, the dromaeosaurids *Sinornithosaurus millenii*, *Microraptor zhaoianus*, and *M. gui*, and the poorly known *Protarchaeopteryx robusta* (Xu, 2002). *Y. longimanus* represents the eleventh theropod species reported from the Early Cretaceous western Liaoning and increases the diversity of the theropod dinosaurs in the Jehol fauna.

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